A Partnership for Modeling the Marine Environment of Puget Sound, Washington

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Award Number: N00014-02-1-0502
http://www.psmem.org/

LONG-TERM GOALS

Puget Sound, Washington, is both the largest fjord in the lower forty-eight states and closest to the substantial urban centers of Seattle, Tacoma, Everett and surrounding communities. The sound has seasonally high annual phytoplankton standing stock and primary production, and they support several economically valuable fisheries. Our long-term goals are to develop quantitative understanding of the Sound's circulation and marine ecosystem, and of the sensitivity of the physical and the biological system to natural and human perturbations; and to develop models of Puget Sound that can aid agencies with responsibilities for environmental management in making informed decisions and serve as marine science education tools.

OBJECTIVES

Our partnership will develop, maintain and operate a suite of flexibly linked simulation models of Puget Sound's circulation and ecosystem, a data management system for archiving and exchanging oceanographic data and model results that are accessible to all members of the partnership as well as to

the regional and oceanographic community, and an effective delivery interface for the model results and observational data for research, education and policy formulation. Our partnership will conduct scientific research aimed at developing fundamental understanding of the Sound's working, as well as addressing practical questions raised by the regional community concerning management of the Sound and its resources. Our partnership will function as an estuarine research node within the NOPP Ocean Information Commons.

APPROACH

The partnership consists of five separate organizations: University of Washington (UW, School of Oceanography and College of Education), Department of Natural Resources and Parks, King County, Washington (KC-DNR), Washington State Department of Ecology (WA-DOE), Puget Sound Naval Shipyard (PSNS)/SPAWAR, and Ocean Inquiry Project (OIP). It is administered from School of Oceanography, UW. Collectively we are operating or developing four dynamically based, predictive models of the Sound's aquatic environment, each with a different spatial coverage (and a fifth module for biogeochemistry), and our goal is to integrate these modeling efforts into a coordinated whole. Our tasks are divided as follows:

- Project coordination: Mitsuhiro Kawase (UW)
- Model operation and development:
    - Puget Sound Circulation Model: Kawase, Bruce Nairn (KC-DNR)
    - Sinclair-Dyes Inlet Model: Robert Johnston (SPAWAR), P.F. Wang (SPAWAR)
    - South Puget Sound Model: Jan Newton (WA-DOE), Skip Albertson (WA-DOE)
    - Duwamish Estuary/Elliott Bay Model: Randy Shuman (KC-DNR)
    - Aquatic Biogeochemistry Model (ABC): Allan Devol (UW), Nairn, Newton
- Data management and infrastructure: Miles Logsdon (UW), Mark Warner (UW)
- Education and visualization: William Winn (UW), Fritz Stahr (OIP)

WORK COMPLETED

We held a regional scientific workshop that had been in our work plan on Friday, April 23, 2004 at the University of Washington, School of Oceanography. The goal of this workshop was to present the current status of marine modeling capabilities in the Puget Sound region as well as develop and refine a subsequent research agenda. It was our desire to collaborate with as many individuals or institutions as possible to formulate regional research priorities and achieve our goals for an integrated modeling framework. An invitation went out to scientists at regional academic institutions, federal and local government agencies,

The workshop was organized into two sections. The morning session included a description of the current PSMEM status including anticipated goals and then focused on participant activities involving current, planned or envisioned modeling projects. There were two additional individual presentations by non-partnership participants (C.J. Beegle-Krause of NOAA HAZMAT team and Correigh Greene of NOAA Fisheries). The afternoon session broke out into three groups of randomly selected participants to focus attention on specific interests such as water quality, aquatic / fisheries resources,

atmospheric – terrestrial – marine interaction, and hazardous materials response. A brief, concluding session by the whole group was held at the end of the meeting, and the meeting agenda and summaries of the breakout group discussions are posted on our web site.

Daily operational hindcasting of Puget Sound circulation is now done routinely, and animation result is posted on our web site. In anticipation of increased computational workload for the second half of our project, we have built a computational cluster consisting of nine Apple Xserve G5s. This cluster takes advantage of cluster resources Apple has developed mainly for the biomedical field, and is set up to run MPI-parallelized computational fluid dynamics codes. We are currently testing the cluster setup, and will migrate our production models to the cluster during the upcoming year.

The one-way linkage between the UW Puget Sound model and PSNS/SPAWAR model of Sinclair and Dyes Inlets is almost complete. The two models are linked at the northern and southern end of Bainbridge Island with the larger model supplying sea surface elevation and temperature/salinity boundary conditions to the Inlets model. In the upcoming year, we will be using the linked model to study the recirculatory flow around Bainbridge Island, analogous to the well-studied recirculation around Vashon Island in the southern main basin of the Sound.

Development of the Aquatic BiogeoChemistry Model (ABC) has continued in the context of simulation of phytoplankton bloom cycles in Budd Inlet, south Puget Sound. However, we have come to realize limitations of the Inlet, whose dynamics is almost entirely driven from the boundary, as a test bed of the model. We are planning to continue model development in a setting that will be more revealing of the internal ecosystem dynamics itself.

During the year, we have completed a version of Virtual Puget Sound (VPS) that runs on desktop computers, allowing it to be used in classrooms. VPS has now been used twice in classes. In the Fall, instructors teaching introductory oceanography classes at the University of Washington and at Seattle Central Community College collaborated to make their courses equivalent, except that the university students used VPS for some exercises while the community college students did the same exercises at sea. VPS was successful at teaching the concepts and principles that were learned in the field, provided a context for learning for students who had little prior experience with the ocean, and made it easier for students to generalise what they learned from one location in Puget Sound to another. This summer, VPS was used every day for two weeks with dyslexic children in grades 4- 6 who were attending an intensive language program at the University of Washington. While not all data analysis is complete at the time of writing, we found that the children learned a great deal about tides, currents and salinity. Their language skills improved and some developed impressive three-dimensional mental models of the bathymetry of Puget Sound.

We have submitted a proposal to NOAA to develop VPS into a game in the context of reponses to hazardous materials events. We also plan to seek funding to make the desktop version of VPS immersive, using virtual reality technology. In addition, we will continue to work with members of the Partnership to make VPS more useful in classes and in other places where people need to learn about what is happening in the Sound.

In support of the Partnership's modeling activities we have been developing a data management system that would hold database for forcing and verification data as well as model results. The database, developed using Access, has been converted to Postgres for greater power and flexibility.

The database is now serving first year data of UW PRISM Puget Sound hydrographic surveys on the web.

RESULTS

The regional workshop was a great success; twenty-six scientists from regional and federal governments including NOAA, USACE, EPA, and Washington State Departments of Fish/Wildlife Services, consulting firms, and academia participated in addition to seventeen participants from the partnership institutions. The partnership has developed a better understanding of the region's need for marine modeling, and the participants' response has given us confidence that our partnership will provide great value for the regional marine science community. Summaries of the breakout groups' discussions are now posted in the Workshop page of the PSMEM web site.

There was a strong desire among the participants that this kind of workshop should be held regularly. We have not planned further workshops in our original proposal but we will consider partnering with other regularly held regional scientific conferences, such as the Pacific Estuarine Research Society and the Georgia Basin – Puget Sound conference,

An accidental oil spill in the night of December 30, 2003 near Point Wells in the north main basin of the sound provided us with an unexpected opportunity for a lagrangian validation of the model's surface flow field. We were able to incorporate the model flow field into the NOAA HAZMAT spill trajectory model for a hindcast of the oil spill trajectory, to compare with a visual observations of the spill made in the following day. The the spill trajectory model correctly hindcasted the southwestward movement of the spill into Port Madison (Fig. 1) although the simulation was highly sensitive to the wind forcing. Nevertheless this has given us confidence that the Puget Sound model can become a useful resource for those responding to short-term environmental accidents. The oil spill simulation was presented at the 2004 Pacific Estuarine Research Society Meeting on May 18 in Port Townsend, WA [1]. We have subsequently submitted a preproposal in response to an RFP from NOAA / University of New Hampshire Coastal Response Research Center to develop an oil spill response model using computer game technology. This preproposal has been accepted.

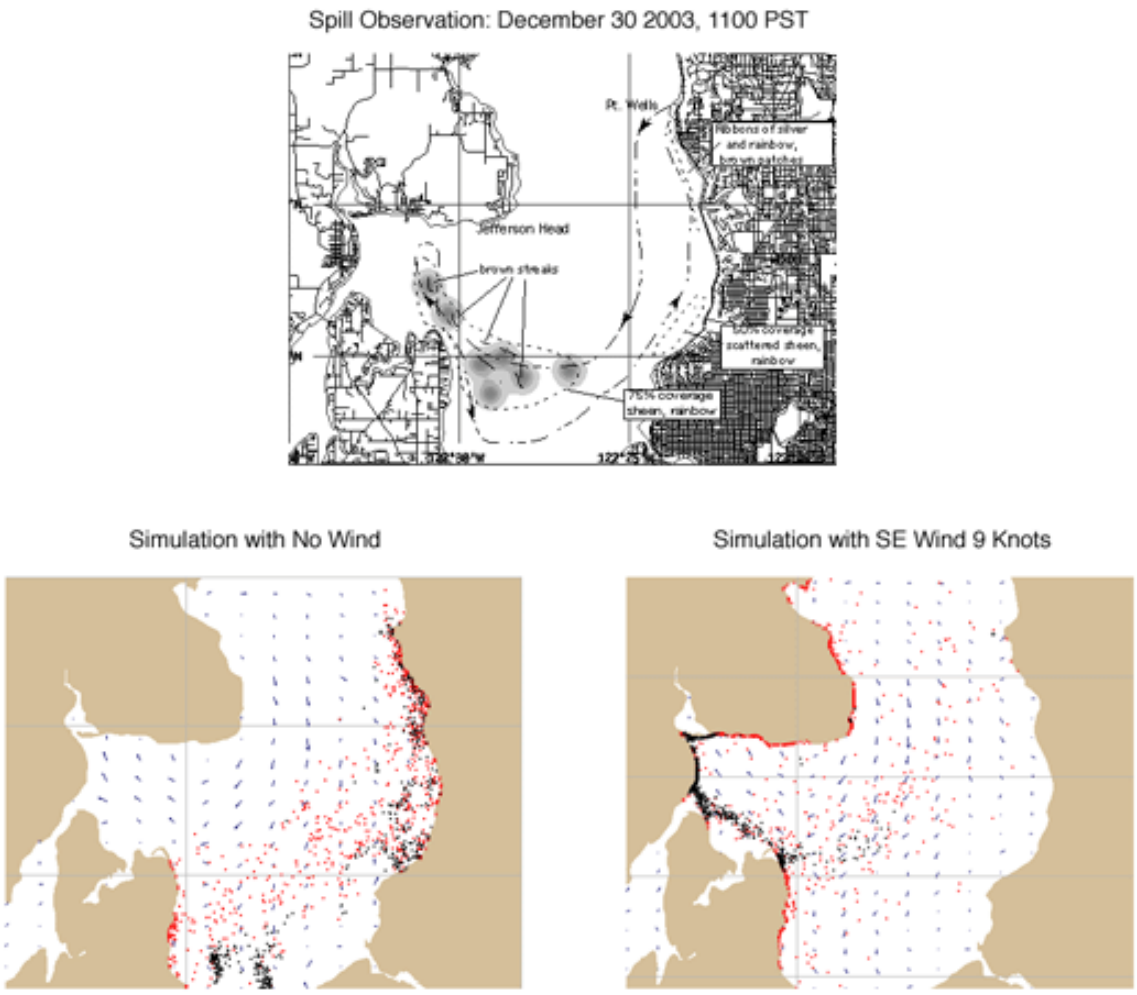

Figure 1: Comparison of an oil spill observation from overflight on December 30, 2003, 1100 PST (top) with simulations without (bottom left) and with (bottom right) wind. The dotted line with arrows in the top panel is the path of the overflight, not the trajectory of the spill.

IMPACT/APPLICATIONS

National Security

An improved modeling capability of the circulation and marine ecosystem of Puget Sound will help local and regional government devise procedures to deal with, for instance, chemical/biological attacks involving harmful agents that may be/need be flushed down into our marine waters, and with terrorism aimed at military and industrial installations that may result in environmental contamination.

Economic Development

Predictive modeling of Puget Sound's circulation and marine ecosystem will have positive impacts on many economic activities taking place in the Sound. For instance, forecasting of harmful algal blooms

(HABs) and better understanding of hypoxia-induced fish kills in the Sound will help commercial fisheries better deal with this threat to their livelihood. Detailed knowledge of currents and hydrography will help diving operators with their underwater work. Understanding longer term variability in water quality leading to marine ecosystems change will help managers of fisheries resources make decisions.

Quality of Life

The Puget Sound region has always enjoyed a quality of life directly related to the quality of our environment. Our models provide tools for evaluating the impact of regional scale actions on the marine environment by predicting response of the latter to potential stressors. Oceanographic knowledge also has direct uses and benefits for those who work and live at sea. For instance, knowledge of currents will help Coast Guard and regional law-enforcement agencies with search and rescue operations and contaminant spill containment.

Science Education and Communication

With the aid of suitable visualizations, support material, and curriculum modules, the model results will be a valuable tool for learning about Puget Sound's marine environment that can be used in classroom settings as well as by the public at large in museums and through the web.

TRANSITIONS

Quality of Life

We are providing modeling resources in terms of expertise and computational hardware to Hood Canal Dissolved Oxygen Project (HCDOP). This collaborative project has been developed in response to concerns of residents of communities around the canal about recurrent fish kills in Southern Hood Canal in recent years, which are believed to be due to persistent hypoxia in the marine waters of this region. HCDOP has received congressional funding as well as funding from National Fish and Wildlife Foundation for FY 05 and 06 for a comprehensive study of hypoxia in Hood Canal encompassing observations and modeling of circulation and biogeochemistry of the marine waters and terrestrial inputs of fresh water, nutrients and organic matter. The project’s goals are to sort out anthropogenic changes in the oxygen level, if any, from natural variabilities, and to assess the effectiveness of proposed remedial measures. We have provided initial estimates of oxygen consumption rates using a simple box model of Puget Sound circulation ([2, 3]).

Science Education and Communication

RELATED PROJECTS

The partnership continues a strong cooperative relationship with Puget Sound Regional Synthesis Model (PRISM, www.prism.washington.edu), a University of Washington project to develop and consolidate University-wide expertise in natural and human environment of the Puget Sound region.

The partnership’s work compliments work being conducted under PSNS & IMF Project ENVVEST [4] to conduct modeling studies of the Sinclair and Dyes Inlet Watershed to assess the impact of CSO

discharges on water quality of the Inlets [5] and support the development of TMDLs for the watershed [6, 7].

As described above, partnership scientists will play an active role in the Hood Canal Dissolved Oxygen Project.

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